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7 SOILS INVESTIGATION

7.1 BACKGROUND

7.1.1 Purpose and Problem Definition

The purpose of this investigation was to determine the presence of munitions constituents (e.g., explosives, heavy metals, perchlorate, and depleted uranium) from range-related activities in surficial soils located within the Jefferson Proving Ground (JPG) Impact Area and an area identified as a Reference/Background Site. Data collected was used to assess the following study questions: 1) Are munitions-related constituents present in surficial soils? 2) Is there a human or ecological health risk associated with munitions constituents at the levels determined to be present? This section describes the soil sampling strategy and rationale and reports the results. Subsequent sections will describe the human health and ecological risk assessments.

7.1.2 Site Description

Jefferson Proving Ground, a 55,265-acre facility in operation from 1941 to 1995, was established to meet the need for conducting research and development tests and production acceptance tests during World War II. Prior to being established as a munitions and ordnance testing facility, JPG land use consisted of farmland and woodland. The types of munitions and ordnance tested at JPG include: propellants, mines, ammunition, cartridge cases, artillery projectiles, mortar rounds, grenades, tank ammunition, bombs, boosters, and rockets. JPG became a subcommand of the U.S. Army Test and Evaluation Command (TECOM) in 1962. Identified for Base Realignment and Closure (BRAC) in 1989, JPG ceased operation in 1995. In 1997, TECOM and the U.S. Fish and Wildlife Service (USFWS) signed a Memorandum of Understanding granting the USFWS a 25-year real estate permit. This has enabled the USFWS to establish the Big Oaks National Wildlife Refuge, encompassing approximately 51,000 acres north of the firing line. The USFWS allows limited public access for hunting, fishing, and tours. JPG is located on portions of Jefferson, Ripley, and Jennings Counties. JPG is approximately 18 miles long and 5 miles wide. The impact area, encompassing 51,000 acres north of the firing line, consists mostly of wooded land and some areas that were chemically (i.e., pesticide application) and physically maintained for certain munitions testing. The firing line, located north of the cantonment area, consisted of 268 gun positions. According to archive reports, there were 50 impact fields with associated safety fans. It is important to note that most of the unexploded ordnance (UXO) contamination is not limited to the impact areas. This is due to the fact that the actual target areas were used only when the detonation and/or impact of the projectile was important to the test; therefore, many of the munitions tests used for velocity measurements, gun tube proofing, or propellant were not fired into specific impact areas and may be found anywhere north of the firing line. Installation personnel voiced their concern for the possible presence of submunitions. The potential for contamination from submunitions fired into the northern portion of the impact area is largely due to the irregular manner in which this type of weapon discharges. For safety purposes, areas into which submunitions were fired were not considered as potential sample areas.

7.2 INVESTIGATION NARRATIVE

7.2.1 Rationale

Soil sampling project personnel performed an initial walkthrough of the JPG impact area March 20 – 22, 2002 and a more extensive site visit May 6 – 10, 2002. The number and type of similar areas, termed strata and substrata, to be sampled was determined through an extensive review of JPG Archive Search Reports, topographical maps, aerial photography, and personal interviews.

7.2.2 Strategy

A stratified random sampling scheme (USEPA, 1989a and 2000) was used to assess the presence of substances of potential concern (SOPC) within surficial soils located within the JPG impact area and reference site. Using this sampling scheme, the area to be studied was divided into two strata. Each stratum is defined as possessing like characteristics (e.g., terrain, soil type, vegetation, location, accessibility, usage patterns, and type/size of munitions fired in to the area) throughout the defined sample area. The two strata consisted of a depleted uranium stratum and a nondepleted uranium stratum. The two strata were further divided into substrata based upon area usage patterns, munitions fired into the area, and topography. Project personnel determined the number of areas to be sampled by identifying sample areas that were representative of the entire impact area north of the firing line. Time and funding constraints also influenced the final number of sample areas that were sampled as part of this assessment.

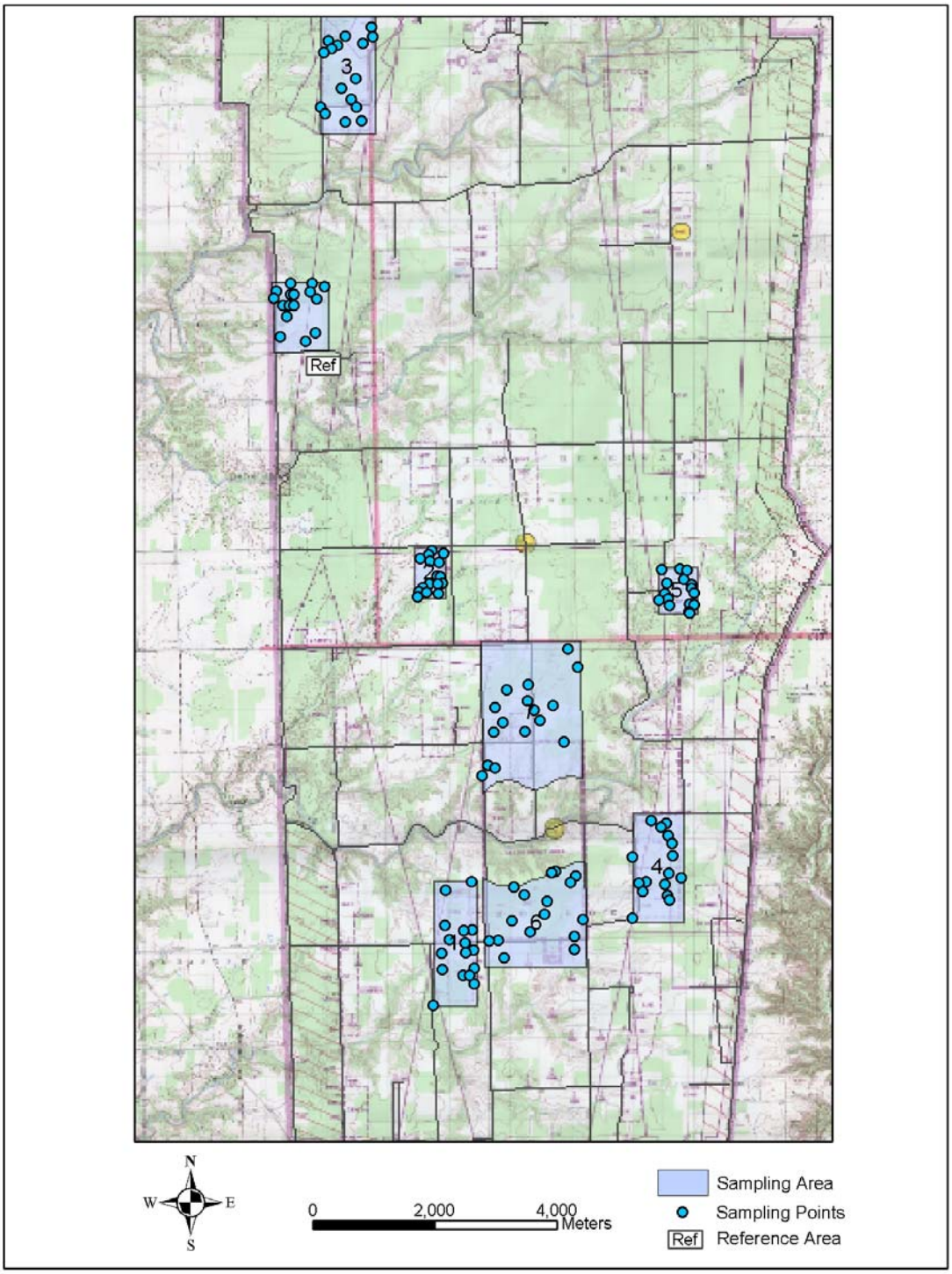
7.2.2.1 Substrata

The following eight substrata were chosen based upon characteristics that were representative of the impact area north of the firing line: five nondepleted uranium sample areas; two depleted uranium sample areas; and a reference site (See Figure 7-1). Impact areas to the north, east, south, and west were chosen to represent the entire range. The reference site was identified as one with similar terrain, soil, and vegetation to that of the impact areas. This site was also identified as an area not having been impacted by munitions-related activities, or any other activities that would result in the deposition of SOPC (e.g., heavy metals, explosives, perchlorate, depleted uranium) that are being assessed as part of this site investigation. Certain impact areas were not chosen for study due to a lack of accessibility and proximity to submunitions impact areas.

7.2.2.2 Sample Locations

Sample locations were randomly selected prior to initiating sampling activities. Sample numbers collected within each stratum were determined based on the following assumptions: Confidence Level (80%), Power (95%), Minimum detectable difference (20%), and Coefficient of Variation (30%). These parameters coincide with those recommended by the USEPA in the "Soil Sampling Quality Assurance User's Guide" (USEPA, 1989b) for sites undergoing preliminary investigations for determining potential risks to human health and the environment. Twenty samples, consisting of sixteen study samples and four quality control/quality assurance (QA/QC) samples, were collected within each study area. A number of bias samples were also collected.

FIGURE 7-1 SOIL SAMPLING POINTS



7.2.3 Composite samples

A composite sampling design approach was used to collect analytical data for this site investigation. Composite sampling is a mechanism for investigating large study sites where time and monetary limitations are sample issues (USEPA, 1989a, 1992, and 2000). Time limitations reflect how much time the study team has access to the site due to range training schedules, and money limitations reflect how many samples/analyses can be performed.

Five point composite samples were collected and used to evaluate each of the defined strata. Using a Geographic Information System (GIS), sample locations were randomly selected prior to initiating sampling activities. To determine the random location, each stratum was subdivided into 5 m^2 mini-grids, 100 per km^2, with a unique number assigned to each mini-grid. Random numbers were generated for sample identification until 16 unique mini-grids were selected. The coordinates for these samples were then entered into handheld Global Positioning Satellite (GPS) units that were used to navigate the sample teams to the predetermined sample locations. The Universal Transverse Mercator (UTM) coordinates for each sample location were recorded in field notebooks.

7.2.4 QA/QC Samples

QA/QC samples were collected to assess field precision objectives. Two field duplicate samples and two split samples were collected within each of the strata. Field duplicate samples were collected adjacent (1.5 ft to the west) to each of the five point sub-sample locations for two sample locations within each of the strata. Field split samples were taken as subsamples of two original field samples within each strata. Collection and analysis of these samples were identical to that of original field samples.

7.3 DATA EVALUATION

Samples were analyzed for parameters using methodologies shown in the JPG Quality Assurance Project Plan (QAPP) (USACHPPM, 2002).

7.3.1 Statistical Evaluation

Statistical tests used to evaluate study data were selected according to the number/percentage of non-detects; sample distribution within each study area (e.g., normality or lognormality); equality of sample variances (e.g., equal or unequal); and criteria with which each parameter of interest is to be compared (e.g., comparison data from a reference/background site or health risk based screening value). The following statistical software packages were utilized to perform various statistical analyses required to assess the JPG data: USEPA *Data Quality Evaluation Statistical Toolbox* (DataQUEST) software (USEPA, 1996); and SPSS® (SPSS Inc., 2000).

7.3.2 Nondetects

Percentage of nondetects was determined for each parameter of interest for the reference site and each study site in order to determine the type of statistical analysis method needed to analyze

data that fell below the method detection limit (MDL). Table 7-1 outlines statistical methods used to analyze data according to the percentage of nondetects within the dataset for each study site (USEPA, 2000).

TABLE 7-1 GUIDELINES FOR ANALYZING DATA WITH NONDETECTS

Percentage of Nondetects	Statistical Analysis Method
< 15%	Replace nondetects with DL/2, DL, or a very small number.
15 % - 50 %	Trimmed mean, Cohen's adjustment, Winsorized mean and standard deviation
> 50 % - 90 %	Tests for proportions (i.e., Fisher's exact test or Chi Square)
> 90 %	Poisson method

7.3.3 Parametric/Nonparametric Tests

Parametric or nonparametric statistical analysis methods were used to compare parameters of interest in the study sites with the reference site. The use of parametric or nonparametric tests was determined by assessing the sample distribution for each dataset (i.e., normal, lognormal, or unknown). The Shaprio-Wilk W Test for normality was used to determine if the dataset exhibited a normal or lognormal distribution. Datasets that followed a normal or lognormal distribution were assessed using parametric testing methods (i.e., Student t-Test). Nonparametric tests (i.e., Fisher's Exact Test, Mann-Whitney Test) were used to assess datasets containing greater than 15% nondetects, or datasets having an unknown distribution. Qualitative analysis was used to assess datasets having greater than 90% nondetects.

7.3.4 Test for Equal Variances

The F-Test for the equality of two variances was used to identify the type of statistical test used to assess data following a normal or lognormal distribution. The Student's two-sample t-Test was used to compare two population means (i.e., reference site vs. study site) where the two population variances were equal. The Satterthwaite's two-sample t-Test was used to compare two population means where the two population variances were unequal.

7.3.5 Test for Outliers

The Dixon's test for outliers was used for datasets where one or more sample points were unusually large compared to all other sample points in the same strata. Even if a sample point was determined to be an outlier, statistical analysis was performed with and without the outlier(s). However, statistical outliers were included in the final data evaluation.

7.3.6 Comparison to Reference Site Data/Human Health Risk Screening Criteria

For metals concentrations to be assessed as part of the risk assessment process, the mean concentrations of metals in the study site must be present above background levels. For datasets that were found to be significantly greater in the study site than in the reference site and that followed a normal or lognormal distribution, the 95% Upper Confidence Limit (UCL) of the dataset was compared to the human health risk screening criteria, established in Appendix L, JPG Data Quality Objectives (DQOs) documented in the JPG QAPP. For datasets that were significantly greater in the study site than the reference site and that followed an unknown distribution, the 99th percentile was compared to the human health risk screening value for the parameter of interest. Explosives and perchlorate datasets followed an unknown distribution. Therefore, the 99th percentile was used to compare explosives and perchlorate datasets to the human health risk screening criteria established in the JPG DQOs for these parameters. The 95% UCL was obtained by collecting samples from across the impact area (within each defined strata) and calculating the average concentration and standard deviation. Assuming that the impact area is heterogeneous, strata were defined in an attempt to group or isolate like areas.

7.4 REFERENCE SITE DATA EVALUATION

7.4.1 Reference Site Identification

The reference site (approximately 0.88 km^2) was located 11 km north of the firing line on West Perimeter Road adjacent to Gate 15 (See Figure 7-1). This area was selected as one having similar characteristics (i.e., soil type, vegetation, species habitat terrain) to the study sites identified for sampling within the JPG impact area. Soils within this area consist of a brown silt loam and are similar to soils located within each of the study areas. Although this area was identified as one having no signs of impact from military munitions, or any other activities that may have resulted in the presence of target analytes, uncertainty exists as to the exact activities that may have taken place within this area throughout the duration of JPG's existence. Though there was evidence of an old homestead in this area, there was no visual evidence of munitions-related activities. Twenty-one samples were collected within this area, consisting of, 16 five-point composite samples; 4 QA/QC samples (i.e., 2 split and 2 duplicate samples); and 1 bias sample collected for comparison to ecological sample results. Sample location coordinates are shown in Table H-1 of Appendix H.

7.4.2 Metals

Of the 13 metals analyzed for at the reference site, 100% of the samples tested for cadmium and silver were below detection limits or had estimated values below the detection limit. Three of the metals, antimony, mercury and molybdenum, were found to have a large number of nondetects. Based upon USEPA guidance (See Table 7-1), a Test for Proportions statistical analysis method was used to compare datasets having a large number of nondetects (> 50%). The 99th percentiles for each of these parameters (See Table 7-2) were below the human health risk screening criteria identified in Table 7-2, as outlined in the JPG DQOs. The remaining eight metals, arsenic, barium, chromium, copper, lead, manganese, nickel, and vanadium were found to be 100% above the laboratory detection limits for each of the parameters of interest. The 99th

percentile for each these parameters, except manganese (See Table 7-2 and Section 7.13.1), were below the human health risk screening criteria for each of the parameters. Depending on the sample distribution of each parameter of interest at the study site and the reference site, a parametric or nonparametric test was used to determine if the parameter of interest was significantly greater in the study site than in the reference site. Table 7-2 lists the sample average, sample median, sample standard deviation, percentage of nondetects, sample distribution, 99th percentile, and human health risk criteria for each parameter of interest.

TABLE 7-2 REFERENCE SITE DATA SUMMARY

	Average (mg/kg)	Median (mg/kg)	STD@ (mg/kg)	%Non-Detects	Sample Distribution	High Value mg/kg (99th Percentile)	Health Risk Criteria (mg/kg)
Antimony	1.79	1.00	0.17	76%	Unknown	1.68	31
Arsenic	5.55	5.29	2.70	0%	Normal	16.10	--
Barium	96.20	91.90	31.35	0%	Normal	146.00	5,400
Cadmium	--	--	--	100	NA	NA	37
Chromium	10.62	10.30	2.77	0%	Unknown	13.90	210
Copper	7.02	6.54	2.16	0%	Normal	11.70	2900
Lead	24.02	20.00	15.30	0%	Unknown	72.30	400
Manganese*	878.86	855.00	418.52	0%	Normal	1970	1800
Mercury	0.054	0.051	0.017	48%	Unknown	0.094	23
Molybdenum	1.03	1.00	0.13	95%	Unknown	1.61	390
Nickel	6.11	5.94	1.81	0%	Normal	11.00	1600
Silver	1.00	1.00	0	100%	NA	NA	390
Vanadium	34.209	22.8	51.6078	0%	Unknown	51.30	550
RDX	0.013	.01	0.007	67%	Unknown	0.040	4
Perchlorate	0.021	0.02	0.015	90%	Unknown	0.071	100

* Value greater than the human health risk screening criteria.
# The metals summaries are inclusive of all quality assurance/quality control samples.
@ Standard Deviation.

7.4.3 Explosives

RDX and perchlorate were detected at the reference site. RDX was detected in the following seven samples collected within the reference site: REF-SL-01 (0.02 mg/kg), REF-SL-05 (0.019 mg/kg), REF-SL-11 (0.018 mg/kg), REF-SL-12 (0.011 mg/kg), REF-SL-18 (0.04 mg/kg), REF-SL-19 (0.016 mg/kg), and REF-SL-20 (0.011 mg/kg). Three of these samples were QA/QC samples (i.e., one duplicate and two split samples), however, RDX was not detected in the original field samples. Perchlorate was detected above the MDL in samples REF-SL-05 (0.071 mg/kg) and REF-SL-18 (0.052 mg/kg). The 99th percentiles, (0.04 mg/kg) and (0.071 mg/kg) for RDX and perchlorate respectively, were below the human health risk screening criteria (4 mg/kg,

RDX and 100 mg/kg, perchlorate) listed in Table 7-3, as outlined in the JPG DQOs. Unlike within the study sites, there were no visual signs of munitions-related activities within the reference site. There was also no signal from the magnetometer handled by Explosive Ordnance Disposal (EOD) technicians signaling the presence of UXO in the area. As a result, it is uncertain whether the reference site chosen was an appropriate background/comparison site (e.g., clean) or whether detections of RDX and perchlorate within this area are suspect (e.g., possible cross contamination). The data was third party validated. There is no evidence of sampling or laboratory error. Reference surface water and sediment samples also were found to contain munitions constituents. For these reasons, we believe that the reference sample results are valid as reported. Because the low levels that were reported do not exceed the human health criteria, no additional sampling is recommended.

TABLE 7-3 STUDY SITE 1 DATA SUMMARY

	Average (mg/kg)	Median (mg/kg)	STD@ (mg/kg)	% Nondetect	Sample Distribution	High Value (mg/kg) (99th Percentile)	Human Health Risk Criteria (mg/kg)	Ho Not Rejected (NR) Rejected (R)
Antimony	--	--	--	100	NA	NA	31	NR
Arsenic	4.47	4.23	1.39	0	Normal	7.22	--	NR
Barium	116.85	89.35	85.08	0	Unknown	473.00	5,400	NR
Cadmium	1.02	1.00	0.11	95	Unknown	1.53	37	NR
Chromium	9.51	9.16	1.72	0	Normal	13.50	210	NR
Copper	34.12	19.45	42.00	0	Unknown	196.00	2900	R
Lead	17.58	16.55	3.67	0	Unknown	29.20	400	NR
Manganese	627.14	562.50	328.30	0	Normal	1440.00	1800	NR
Mercury	0.050	0.040	0.027	81	Unknown	0.139	23	NR
Molybdenum	1.16	1.00	0.34	76	Unknown	2.21	390	NR
Nickel	5.16	4.97	1.46	0	Normal	8.33	1600	NR
Silver	--	--	--	100	NA	NA	390	NR
Vanadium	21.3	20.2	4.67	0	Normal	28.50	550	NR
RDX	0.010	0.010	0.002	95	Unknown	0.018	4	NA
Perchlorate	0.033	0.020	0.033	76	Unknown	0.110	100	NA

NA – Not Analyzed
@STD – Standard Deviation
Ho – Null Hypothesis

7.5 STUDY SITE 1 DATA EVALUATION (COMBINED IMPACT AREAS 3 WEST (W), 3.3 W, 4.2 W, AND 4.5 W)

7.5.1 Site Identification

Study Site 1 (approximately 1.5 km^2) combined impact areas 3 West (W), 3.3 W, 4.2 W, and 4.5 W, as designated on the installation topographic map (See Figure 7-1). This study site, a substrata of the nondepleted uranium strata, was located 3.5 km north of the firing line, west of the depleted uranium impact area. This area was observed to be a heavily impacted area. JPG archive records indicate that testing activities in this area included: propellant, fuse, high explosive (HE) shell, small canister and illuminating munitions tests. Types of ordnance fired into this area include 105 and 155mm howitzers, 81mm mortars, 57, 75, 105 and 106 mm recoilless. This area consisted of both wooded and nonwooded areas containing a high amount of shrubbery. Soils in this area were poorly drained to somewhat poorly drained with a seasonally high water table. These soils typically have a grayish brown silt loam surface layer about 6 inches thick. The subsoil was a light brownish gray, mottled silt loam in the upper part and a yellowish brown, mottled silt loam and strong brown clay in the lower part (Jefferson County Soil Survey Map, 1985). The soils in this area were similar to soils in the reference site. Twenty-two samples were collected within this area, consisting of, 16 five-point composite samples; 4 QA/QC samples (i.e., 2 split and 2 duplicate samples); and 2 bias samples collected for comparison to ecological sample results. Sample location coordinates are shown in Table H-2

7.5.2 Metals

Of the 13 metals analyzed for at Study Site 1, 100% of the samples tested for antimony and silver were below MDLs or had estimated values below the detection limit. Cadmium was detected above the MDL in only one sample, ST1-SL-13 (1.53 mg/kg). However, this value (99^{th} percentile) was below the human health risk criteria of 37 mg/kg defined in the JPG DQOs. Mercury and molybdenum had a high percentage (> 50%) of nondetects. The Fisher's Exact Test for Proportions statistical analysis method was used to compare the proportions of these parameters in Study Site 1 with the proportions of detects in the reference site. Using this statistical method, it was determined that the proportions of detects for mercury and molybdenum were not significantly greater in the study site than the reference site. The remaining eight metals, arsenic, barium, chromium, copper, lead, manganese, nickel, and vanadium were detected above the laboratory MDLs in all samples collected within this area. Depending on the sample distribution of each parameter of interest at both the study site and the reference site, a parametric or nonparametric test was used to determine if the mean concentration, median concentration, or proportions of detects for each parameter of interest was significantly greater in the study site than the referenced site. Of these remaining metals, only copper was found to be significantly greater in Study Site 1 than in the reference site. Using the Dixon's test for outliers, the high value for copper (196 mg/kg) at this site was determined to be an outlier. Statistical analysis was performed with and without the outlier. The nonparametric, Mann-Whitney test (for unknown sample distribution) was used to compare the datasets with the outlier included while the Student Two Sample t-Test (for normal or lognormal sample distributions) was used to compare the datasets without the outlier. In each case, the median for

this dataset was significantly greater in Study Site 1 than in the reference site. Though the study site was significantly greater than the reference site, the 99th percentile (196 mg/kg) was less than the human health risk screening criteria (2,900 mg/kg) identified in Table 7-3, as outlined in the JPG DQOs.

7.5.3 Explosives

RDX and perchlorate were detected above the laboratory MDLs at Study Site 1. RDX was detected in samples ST1-SL-12 and ST1-SL-22 (0.011 mg/kg and 0.018 mg/kg, respectively). Perchlorate was detected in the following five samples collected at this site: ST1-SL-11 (0.056 mg/kg), ST1-SL-14 (0.025 mg/kg), ST1-SL-15 (0.036 mg/kg), ST1-SL-16 (0.11 mg/kg), and ST1-SL-20 (0.04 mg/kg). The 99th percentile for each of these parameters, 0.018 (RDX) and 0.11 (perchlorate), were below the human health risk screening criteria, 4 mg/kg (RDX) and 100 mg/kg (perchlorate), identified in Table 7-3, as outlined in the document, JPG DQOs. No other explosives were detected at this site.

7.6 STUDY SITE 2 DATA EVALUATION (IMPACT AREA 10 W)

7.6.1 Site Identification

Study Site 2 (approximately 0.30 km^2), designated as Impact Area 10 W on the installation topographic map, was a substrata of the nondepleted uranium sample strata. This area, located 9.5 km north of the firing line and 2.5 km east of West Perimeter Road, was observed to contain a high number of impact craters (See Figure 7-1). Types of ordnance fired into this area included 105mm, 155mm, and 90 mm HE rounds. The majority of the sample area consisted of grassland and shrubbery. The terrain in this area was moderately to gently sloping, with strong slopes (12 to 18 percent) along the tributary traversing the southern portion of the study area. The soils in this area consisted of silt loams of various soil descriptions depending on the topography of the area. The soils in this area were similar to the soils in the reference site. The southern portion of the sample area was wooded, and traversed by a tributary of Marble Creek, which empties into Big Creek. Twenty-one samples were collected within this area, consisting of 16 five-point composite samples; 4 QA/QC samples (i.e., 2 split and 2 duplicate samples); and 1 bias sample. Sample location coordinates are shown in Table H-2.

7.6.2 Metals

One hundred percent of the samples analyzed for antimony, cadmium, and silver were below laboratory MDLs. Mercury and molybdenum had a high percentage of (> 50%) nondetects. Using the Fisher's Exact test, it was determined that the proportions of detects for mercury were significantly greater in the reference site than in Study Site 2. There was not a significant difference in the proportions of detects for molybdenum in Study Site 2 and the reference site. The remaining eight metals, arsenic, barium, chromium, copper, lead, manganese, nickel, and vanadium were detected above MDLs within this study site. Depending on the sample distribution of each parameter of interest at both the study site and the reference site, a parametric or nonparametric test was used to determine if the mean concentration, median concentration, or the proportions of detects were significantly greater in the study site than in the

reference site. The nonparametric, Mann-Whitney statistical analysis method, was used to compare each of these parameters in Study Site 2 with the reference site. Of these remaining metals, only copper was significantly greater in the study site than in the reference site ($p < 0.2$). Though copper was significantly greater in the study site than the reference site, the 99th percentile (65.3 mg/kg) was below the human health screening criteria (2,900 mg/kg) for this parameter. Sample data is shown in Table 7-4.

TABLE 7-4 STUDY SITE 2 DATA SUMMARY

	Average (mg/kg)	Median (mg/kg)	STD@ (mg/kg)	% Nondetect	Sample Distribution	High Value (mg/kg) (99th Percentile)	Human Health Risk Criteria (mg/kg)	Ho Not Rejected (NR) Rejected (R)
Antimony	1.00	1.00	0	100	NA	NA	31	NR
Arsenic	4.87	4.06	3.43	0	Unknown	10.90		NR
Barium	157.70	104.00	114.40	0	Unknown	415.00	5,400	NR
Cadmium	1.00	1.00	0	100	NA	NA	37	NR
Chromium	10.05	9.58	2.18	0	Unknown	15.50	210	NR
Copper	11.60	8.17	12.80	0	Unknown	65.30	2900	R
Lead	19.90	16.70	8.75	0	Unknown	34.60	400	NR
Manganese	460.20	361.00	372.10	0	Unknown	1250.00	1800	NR
Mercury	0.043	0.040	0.006	76	Unknown	0.059	23	NR
Molybdenum	1.10	1.00	0.32	90	Unknown	2.35	390	NR
Nickel	5.62	4.97	3.10	0	Unknown	16.40	1600	NR
Silver	1.00	1.00	0	100	NA	NA	390	NR
Vanadium	23.90	19.70	8.20	0	Unknown	49.80	550	NR
RDX	--	--	--	100	NA	NA	4	NA
Perchlorate	--	--	--	100	NA	NA	100	NA

NA – Not Analyzed ?
@STD – Standard Deviation
Ho – Null Hypothesis

7.6.3 Explosives

One hundred percent of the samples analyzed for explosives and perchlorate at this site were below the laboratory MDLs. Sample data is shown in Table 7-4.

7.7 STUDY SITE 3 DATA EVALUATION (IMPACT AREA 18 W)

7.7.1 Site Identification

Study Site 3 (approximately 2.25 km^2), designated as Impact Area 18W on the installation topographic map, was a substrata of the nondepleted uranium sample strata. This area, located 16 km north of the firing line and 2 km east of West Perimeter Road, was observed to be a heavily impacted area (See Figure 7-1). Archive reports indicated that 60 mm rounds and 81 mm illuminating rounds were fired into this area. Interviews with long-term JPG personnel

indicated the potential for White Phosphorus to be present in the soils at this sample area. This area consisted of both wooded and nonwooded areas. Tributaries in this study site flowed to the southwest into Graham Creek. Soils in this area were predominately Cobbsfork soils. These soils are poorly drained, nearly level soils with a dark grayish brown silt loam surface layer. The upper part of the subsoil is light gray, mottled silt loam and silty clay loam. The lower part is a gray, dark yellowish brown, and yellowish brown, mottled silt loam and silty clay loam. The soils in this area were similar to the soils in the reference site. Twenty samples were collected within this area. These samples consisted of 16 five-point composite samples and 4 QA/QC samples (i.e., 2 split and 2 duplicate samples). No bias samples were collected in this area. Sample location coordinates are shown in Table H-4.

7.7.2 Metals

One hundred percent of the samples analyzed for mercury and silver at this site were below laboratory MDLs. Antimony, cadmium, and molybdenum had a high percentage of nondetects (> 50%). The study site had one more detect than the reference site for both cadmium and molybdenum. Therefore, upon qualitative analysis, it was determined that there was not a significant difference in the proportions of detects in Study Site 3 and the proportions of detects in the reference for each of these parameters. The nonparametric, Fisher's Exact Test for Proportions, was used to determined that the proportions of detects of antimony in Study Site 3 were significantly greater than in the reference site. Though the proportions of detects for antimony at Study Site 3 was significantly greater than the reference site, the 99th percentile for antimony (2.49 mg/kg) at Study Site 3 were below the human health risk criteria (31 mg/kg) identified in Table 7-5. The remaining eight metals, arsenic, barium, chromium, copper, lead, manganese, nickel, and vanadium, were detected in 100 % of the samples collected at Study Site 3 and followed an unknown distribution. Using the nonparametric, Mann-Whitney test, it was determined each of the parameters was not significantly greater in Study Site 3 than in the reference site.

7.7.3 Explosives

RDX was detected in samples ST3-SL-01 (0.04 mg/kg), ST3-SL-03 (0.04 mg/kg), and ST-SL-05 (0.06 mg/kg). The 99th percentile (0.06 mg/kg) was below the human health risk criteria (4 mg/kg) identified in Table 7-5, as outlined in the JPG DQOs. There were no other explosives detected at this site. Perchlorate was not detected at this site.

TABLE 7-5 STUDY SITE 3 DATA SUMMARY

	Average (mg/kg)	Median (mg/kg)	STD@ (mg/kg)	% Nondetect	Sample Distribution	High Value (mg/kg) (99th Percentile)	Human Health Risk Criteria (mg/kg)	Ho Not Rejected (NR) Rejected (R)
Antimony	1.36	1.00	0.53	55	Unknown	2.49	31	R
Arsenic	4.08	3.44	2.35	0	Unknown	8.3		NR
Barium	110.60	58.85	206.00	0	Unknown	979	5,400	NR
Cadmium	1.04	1.00	0.19	95	Unknown	1.84	37	NR
Chromium	9.05	8.88	2.17	0	Unknown	13.10	210	NR
Copper	4.40	4.16	1.32	0	Unknown	7.94	2900	NR
Lead	13.80	12.75	3.95	0	Unknown	27.70	400	NR
Manganese	196.10	125.00	191.10	0	Unknown	683.00	1800	NR
Mercury	--	--	--	100	NA	NA	23	NR
Molybdenum	1.08	1.00	0.27	90	Unknown	2.17	390	NR
Nickel	3.31	3.01	1.04	0	Unknown	5.74	1600	NR
Silver	--	--	--	100	NA	NA	390	NR
Vanadium	22.74	18.75	9.56	0	Unknown	45.30	550	NR
RDX	0.016	0.010	0.014	85	Unknown	0.060	4	NA
Perchlorate	--	--	--	100	NA	NA	100	NA

NA – Not Analyzed ?
@STD – Standard Deviation
Ho – Null Hypothesis

7.8 STUDY SITE 4 DATA EVALUATION (IMPACT AREAS 4.5 EAST (E) AND 5.3 E)

7.8.1 Site Identification

Study Site 4 (approximately 1.6 km^2), designated as Impact Areas 4.5 East (E) and 5.3 E on the installation topographic map, was a substrata of the nondepleted uranium sample strata. This study site, located 4.7 km north of the firing line and 0.75 km to the east of the depleted uranium sample area, was observed to have a high amount of impact craters (See Figure 7-1). Archive reports indicated that 81 mm mortar, 4.2-inch mortar inert and HE, and 105 howitzer rounds were fired into this area. Past land maintenance activities have involved the use of both chemical and mechanical methods to control vegetation growth for the purpose of observing munitions testing at this location. Chemical applications (i.e., bromocil) were used prior to the mechanical maintenance activities that had occurred over the past 20 years. Past maintenance practices have most likely resulted in this becoming a nonwooded, grassy area. This area consisted of gently sloping to nearly level terrain, with some moderately sloping areas. Soils in areas of nearly level terrain typically consisted of a deep, poorly drained grayish brown silt loam surface layer. Areas of gently sloping to moderately sloping terrain consisted of well-drained soils on the uplands,

with a dark yellowish brown silt loam and brown silty clay loam surface layer. The soils in this area were similar to the soils in the reference site. Twenty samples were collected within this area. These samples consisted of 16 five-point composite samples and 4 QA/QC samples (i.e., 2 split and 2 duplicate samples). No bias samples were collected in this area. Sample location coordinates are shown in Table H-5.

7.8.2 Metals

One hundred percent of the samples analyzed for cadmium, mercury, and silver were below the MDLs. There was a high percentage of nondetects (> 50%) for antimony and molybdenum at the study site. Upon qualitative analysis, it was determined that there was no significant difference between the proportion of detects for antimony and molybdenum at Study Site 4 and the proportions of these parameters at the reference site. Using the nonparametric, Mann-Whitney test, only copper and vanadium were determined to be significantly greater in Study Site 4 than in the reference site. Though the medians for these parameters were significantly greater in the study site than in the reference site, the 99th percentiles, (44.6 mg/kg) and (46.9 mg/kg) for copper and vanadium respectively, were less than the human health risk screening criteria (2,900 mg/kg, copper) and (550 mg/kg, vanadium) identified in Table 7-6, as outlined in the JPG DQOs.

TABLE 7-6 STUDY SITE 4 DATA SUMMARY

	Average (mg/kg)	Median (mg/kg)	STD@ (mg/kg)	% Nondetect	Sample Distribution	High Value (mg/kg) (99th Percentile)	Human Health Risk Criteria (mg/kg)	Ho Not Rejected (NR) Rejected (R)
Antimony	1.23	1.00	0.73	90	Unknown	3.91	31	A
Arsenic	6.34	4.31	7.01	0	Unknown	34.00	--	A
Barium	81.00	55.30	100.50	0	Unknown	97.80	5,400	A
Cadmium	--	--	--	100	NA	NA	37	A
Chromium	11.06	10.45	3.33	0	Unknown	18.8	210	A
Copper	10.78	7.75	9.08	0	Unknown	44.6	2900	R
Lead	18.28	14.00	8.37	0	Unknown	43	400	A
Manganese	216.50	120.00	153.50	0	Unknown	553	1800	A
Mercury	--	--	--	100	NA	NA	23	A
Molybdenum	1.04	1.00	0.19	95	Unknown	1.87	390	A
Nickel	4.34	3.96	1.56	0	Unknown	7.61	1600	A
Silver	--	--	--	100	NA	NA	390	A
Vanadium	26.40	24.90	9.16	0	Unknown	46.90	550	R
RDX	0.015	0.010	0.014	85	Unknown	0.069	4	NA
Perchlorate	0.017	0.020	0.007	90	Unknown	0.029	100	NA

A -
NA – Not Analyzed
@STD – Standard Deviation
Ho – Null Hypothesis

7.8.3 Explosives

Perchlorate was detected in samples ST4-SL-16 (0.029 mg/kg) and ST4-SL-20 (0.028mg/kg). The 99th percentile (0.029 mg/kg) was below the human health risk criteria (100 mg/kg) for soil, as established by USACHPPM. RDX was detected in samples ST4-SL-13 (0.039 mg/kg), ST4-SL-14 (0.069 mg/kg), and ST4-SL-16 (0.019 mg/kg). The 99th percentile (0.069 mg/kg) was below the human health risk criteria (4 mg/kg) for RDX identified in Table 7-6, as outlined in the JPG DQOs. There were no other explosives detected at this site.

7.9 STUDY SITE 5 DATA EVALUATION (IMPACT AREA 9.8 E)

7.9.1 Site Identification

Study Site 5 (approximately 4.8 km^2), designated as Impact Area 9.8 E on the installation topographical map, was a substrata of the nondepleted uranium sample strata. This area, located 9.5 km north of the firing line and 2 km west of East Perimeter Road, was observed to be a very heavily impacted area (See Figure 7-1). Archive reports indicated that 105 and 155 mm HE and inert rounds were fired into this area. This area consisted of dense, low lying vegetation, as well as wooded areas. The terrain in this area ranges from nearly level to moderately sloping. The soils in this area consist of silt loams of various soil descriptions, depending on the topography of the area. The majority of the soils in this sample area were poorly drained, nearly level soils with a dark grayish brown silt loam surface layer. The upper part of the subsoil of this soil type is a light gray, mottled silt loam and silty clay loam. The lower part is a gray, dark yellowish brown, and yellowish brown, mottled silt loam and silty clay loam. The soils in this area were similar to the soils in the reference site. Twenty-one samples were collected within this area, consisting of 16 five-point composite samples; 4 QA/QC samples (i.e., 2 split and 2 duplicate samples); and 1 bias sample. Sample location coordinates are shown in Table H-6.

7.9.2 Metals

Samples analyzed for antimony, cadmium, mercury, molybdenum, and silver at Study Site 5 had a high percentage (> 50%) of nondetects. Due to cadmium and silver having greater than 90% nondetects, qualitative analysis was used to determine that there was no significant difference between the proportions of detects for these parameters at Study Site 5 and the proportions of these parameters at the reference site. The Fisher's Exact test was used to determine that the proportions of detects for antimony and molybdenum were not significantly greater in Study Site 5 than the reference site. The proportions of detects for mercury in Study Site 5 were not significantly greater than in the reference site. Of the remaining eight metals, only copper was found to be significantly greater in Study Site 5 than in the reference site. Even though copper was significantly greater in the study site than the reference site, the 99th percentile (71 mg/kg) for this dataset was below the human health risk screening criteria (2,900 mg/kg) identified in Table 7-7, as outlined in the JPG DQOs.

TABLE 7-7 STUDY SITE 5 DATA SUMMARY

	Average (mg/kg)	Median (mg/kg)	STD@ (mg/kg)	% Nondetect	Sample Distribution	High Value (mg/kg) (99% Percentile)	Human Health Risk Criteria (mg/kg)	Ho Not Rejected (NR) Rejected (R)
Antimony	1.14	1.00	0.42	76	Unknown	2.90	31	NR
Arsenic	4.32	3.38	2.47	0	Unknown	9.87	--	NR
Barium	52.70	46.60	17.10	0	Normal	103.00	5,400	NR
Cadmium	1.05	1.00	0.22	95	NA	2.03	37	NR
Chromium	9.77	9.35	2.56	0	Unknown	16.60	210	NR
Copper	17.80	11.00	18.64	0	Unknown	71.00	2900	R
Lead	16.10	14.00	5.59	0	Unknown	32.50	400	NR
Manganese	296.00	94.20	378.50	0	Unknown	1230.00	1800	NR
Mercury	0.0431	0.040	0.011	90	Unknown	0.088	23	NR
Molybdenum	1.04	1.00	0.13	85	Unknown	1.58	390	NR
Nickel	3.99	3.71	1.52	0	Normal	6.97	1600	NR
Silver	1.08	1.00	0.37	95	Unknown	2.70	390	NR
Vanadium	21.80	20.60	6.80	0	Unknown	36.90	550	NR
RDX	0.018	0.010	0.021	81	Unknown	0.098	4	NA
Perchlorate	0.030	0.020	0.025	66	Unknown	0.093	100	NA
2,4 Dinitrotoluene	0.047		0.122	95	Unknown	0.58	120	NA
2,6 Dinitrotoluene	0.012		0.008	95	Unknown	0.046	61	NA

NA – Not Analyzed
@STD – Standard Deviation
Ho – Null Hypothesis

7.9.3 Explosives

RDX, 2,4 dinitrotoluene, 2,6 dinitrotoluene, and perchlorate were detected at this study site. RDX was detected in the following five samples: ST5-SL-04 (0.024 mg/kg), ST5-SL-05 (0.011mg/kg), ST5-SL-07 (0.04 mg/kg), ST5-SL-17 (0.098 mg/kg), and ST5-SL-19 (0.049 mg/kg). The 99th percentile (0.098 mg/kg) was below the human health risk criteria (4 mg/kg) identified in Table 7-7. The explosives 2,4 dinitrotoluene and 2,6 dinitrotoluene were both detected in sample ST5-SL-09 (0.58 mg/kg and 0.046 mg/kg respectively). Each of these concentrations was below the human health risk screening criteria identified in the JPG DQOs. Perchlorate was detected in the following seven of the samples collected within Study Site 5: ST5-SL-04 (0.076 mg/kg), ST5-SL-11 (0.076 mg/kg), ST5-SL-13 (0.042 mg/kg), ST5-SL-14 (0.027 mg/kg), ST5-SL-15 (0.033 mg/kg), ST5-SL-16 (0.063 mg/kg), and ST5-SL-18

(0.093 mg/kg). The 99th percentile (0.093 mg/kg) was below the human health risk screening criteria (100 mg/kg), as established by USACHPPM. There were no other explosives detected at this site.

7.10 STUDY SITE 6 DATA EVALUATION (SUBSTRATA OF THE DU IMPACT STRATA LOCATED IN THE SOUTHERN PORTION OF THE DU IMPACT AREA)

7.10.1 Site Identification

Study Site 6 (approximately 2.0 km^2) was located in the southern portion of the DU impact area as designated on the installation topographic map (See Figure 7-1). Test rounds were scattered throughout the sample area due to the nature of the various types of munitions testing which have occurred in this area. However, in order to minimize dispersal of DU particles, test items were fired into two cloth targets located 3000 meters from the firing line and one in the northern portion of this area located 4000 meters from the firing line. According to JPG personnel, this sample area was used for munitions testing prior to being designated as the DU impact area. Study personnel surveyed HE ordnance (i.e., 155 mm rounds) in the sample area during the site visit. Multiple craters and UXO were surveyed in this area. This area consisted of wooded and nonwooded areas. The majority of the terrain in this area was nearly level. The soil in this area had a grayish brown silt loam surface layer. The subsurface layer, extending about 80 inches in depth, consisted of a light brownish gray silt loam in the upper part and a brown, firm clay loam in the lower part. The soils in this area were similar to the soils in the reference site. Twenty-three samples were collected within this area, consisting of 16 five-point composite samples; 4 QA/QC samples (i.e., 2 split and 2 duplicate samples); and 3 bias samples. Sample location coordinates are shown in Table H-7.

7.10.2 Metals

One hundred percent of the samples analyzed for antimony, cadmium, and silver were below MDLs. Mercury and molybdenum had a high percentage of nondetects (> 50%). Using the Fisher's Exact test, it was determined that Study Site 6 had a significantly greater proportion of detects for mercury than the reference site. However, the 99th percentile (0,085 mg/kg) for mercury at Study Site 6 was below the human health risk screening criteria (23 mg/kg). Using the Fisher's Exact statistical analysis method, it was determined that the proportions of detects for molybdenum were not significantly greater in Study Site 6 than in the reference site. Of the remaining eight metals, only copper was significantly greater in Study Site 6 than in the reference site. The Mann-Whitney statistical analysis method was used to determine whether copper was significantly greater in the study site than in the reference site. The Dixon's test for outliers determined that there were no outliers present in this dataset. Though copper was significantly greater in the study site than in the reference site, the 99th percentile (17.1 mg/kg) for copper was below the human health risk criteria (2,900 mg/kg) identified in Table 7-8.

TABLE 7-8 STUDY SITE 6 DATA SUMMARY

	Average (mg/kg)	Median (mg/kg)	STD@ (mg/kg)	% Nondetect	Sample Distribution	High Value (mg/kg) (99th Percentile)	Human Health Risk Criteria (mg/kg)	Ho Not Rejected (NR) Rejected (R)
Antimony	--	--	--	100	NA	NA	31	NR
Arsenic	3.90	2.32	3.79	0	Unknown	15.20	--	NR
Barium	85.40	76.60	37.80	0	Normal	182.00	5,400	NR
Cadmium	--	--	--	100	NA	NA	37	NR
Chromium	9.16	8.12	3.38	0	Unknown	19.10	210	NR
Copper	8.34	8.23	3.20	0	Normal	17.10	2900	R
Lead	16.00	15.30	4.70	0	Unknown	28.20	400	NR
Manganese	280.50	83.30	390.50	0	Unknown	1010.00	1800	NR
Mercury	0.043	0.040	0.009	87	Unknown	0.085	23	NR
Molybdenum	1.02	1.00	0.11	96	Unknown	1.54	390	NR
Nickel	4.14	2.94	2.63	0	Unknown	10.40	1600	NR
Silver	--	--	--	100	NA	NA	390	NR
Uranium	6.47	2.78	11.2	0	NA	45.8	200	NA
Vanadium	20.20	16.30	10.80	0	Unknown	55.10	550	NR
RDX	0.015	.010	0.016	83	Unknown	0.083	4	NA
Perchlorate	0.029	0.020	0.023	70	Unknown	0.097	100	NA
2,4,6 Trinitrotolune	0.012		0.010	91	Unknown	0.06	12	NA

NA – Not Analyzed
@ – Standard Deviation
Ho – Null Hypothesis

7.10.3 Explosives

Of the explosives analyzed for at this site, 2,4,6 Trinitrotoluene, and RDX and perchlorate were detected. 2,4,6 Trinitrotoluene was detected in samples ST6-SL-05 (0.012 mg/kg) and ST6-SL-22 (0.06 mg/kg). Each of these concentrations was below the human health risk screening criteria (12 mg/kg) identified in Table 7-8, as outlined in the JPG DQOs. RDX was detected in samples ST6-SL-02 (0.014 mg/kg), ST6-SL-21 (0.022 mg/kg), ST6-SL-22 (0.037 mg/kg), and ST6-SL-23 (0.083 mg/kg). The 99th percentile (0.083 mg/kg) was below the human health risk screening criteria (4 mg/kg) identified in Table 7-8. Perchlorate was detected in the following six samples collected at this study site: ST6-SL-01 (0.062 mg/kg), ST6-SL-04 (0.033 mg/kg), ST6-SL-07 (0.093 mg/kg), ST6-SL-10 (0.097 mg/kg), ST6-SL-14 (0.056 mg/kg), and ST6-SL-23 (0.048 mg/kg). The 99th percentile (0,097mg/kg) for perchlorate was below the human health risk screening criteria (100 mg/kg) identified in Table 7-8.

7.11 STUDY SITE 7 DATA EVALUATION (SUBSTRATA OF THE DU IMPACT STRATA LOCATED IN THE NORTHERN PORTION OF THE DU AREA)

7.11.1 Site Identification

Study Site 7 was a substrata of the DU impact strata. This area (approximately 2.25 km^2) consisted of the northern portion of the DU impact area (See Figure 7-1). According to long-term installation personnel, impacts in this sample area occurred as a result of test items fired into the southern portion of the impact area that ricocheted into the northern portion of the impact area. The majority of this sample area consisted of nearly level terrain. The majority of the soil consisted of a poorly drained grayish brown silt loam surface layer. The subsurface layer, extending about 80 inches in depth, consisted of a light brownish gray silt loam in the upper part and a brown, firm clay loam in the lower part. This sample area was traversed northeast to southwest by a tributary of Big Creek. The terrain along this tributary was moderate to steep sloping. The soils in this area were silt loams of various soil descriptions depending on the terrain. The soils in this area were similar to the soils in the reference site. The area consisted of both wooded and nonwooded terrain. Twenty-two samples were collected within this area, consisting of 16 five-point composite samples; 4 QA/QC samples (i.e., 2 split and 2 duplicate samples); and 2 bias samples (collected for comparison with ecological samples). Sample location coordinates are shown in Table H-8.

7.11.2 Metals

One hundred percent of the samples collected and analyzed for antimony, cadmium, and silver were below the MDLs. Mercury and molybdenum had a high percentage of nondetects (> 50%). Upon qualitative analysis, it was determined that the proportions of detects for molybdenum in Study Site 7 were not significantly greater than the proportions of detects in the reference site. The Fisher's Exact test determined that the proportions of detects in Study Site 7 were significantly greater than the proportions of detects for mercury in the reference site. However, the 99th percentile (0.094 mg/kg) for mercury in the Study Site 7 was below the human health risk criteria (23 mg/kg). Using the Mann-Whitney test, it was determined that the median for each of the remaining eight metals was significantly greater in the reference site than in the study site. The 99th percentiles for each of these parameters (except manganese, See Table 7-9 and Section 7.13.2) were below the human health risk-screening criteria's identified in Table 7-9, as outlined in the JPG DQOs. Though the 99th percentile (2470 mg/kg) for manganese was above the human health risk screening criteria (1970 mg/kg), this was not determined to be significant due to the mean concentration of manganese in Study Site 7 (415.2 mg/kg) being less than the reference site (878.6 mg/kg).

7.11.3 Explosives

RDX and perchlorate were detected at this site. RDX was detected in sample ST7-SL-22 (0.04 mg/kg). This concentration (99th percentile) was below the human health risk criteria (4mg/kg) identified in Table 7-9. Perchlorate was detected in 68 % of the samples collected at this study site (See Table 7-9 for samples with concentrations above the detection limit). The 99th

percentile (0.18 mg/kg) for perchlorate was below the human health risk screening criteria (100 mg/kg) identified in Table 7-9.

TABLE 7-9 STUDY SITE 7 DATA SUMMARY

	Average (mg/kg)	Median (mg/kg)	STD@ (mg/kg)	% Nondetect	Sample Distribution	High Value (mg/kg) (99th Percentile)	Human Health Risk Criteria (mg/kg)	Ho Not Rejected (NR) Rejected (R)
Antimony	--	--	--	100	NA	NA	31	NR
Arsenic	4.06	3.95	1.77	0	Unknown	7.98	--	NR
Barium	64.70	55.50	30.20	0	Unknown	143.00	5,400	NR
Cadmium	--	--	--	100	NA	NA	37	NR
Chromium	8.04	7.62	2.11	0	Unknown	14.80	210	NR
Copper	6.39	5.73	2.79	0	Unknown	14.80	2900	NR
Lead	17.50	16.40	6.20	0	Unknown	30.40	400	NR
Manganese*	415.20	187.50	577.30	0	Unknown	2470.00	1800	NR
Mercury	0.0456	0.040	0.0128	73	Unknown	0.094	23	NR
Molybdenum	1.02	1.00	0.07	95	Unknown	1.35	390	NR
Nickel	3.45	2.84	1.78	0	Unknown	7.25	1600	NR
Silver	--	--	--	100	NA	NA	390	NR
Uranium	2.35	2.36	0.107	0	NA	2.52	200	NA
Vanadium	20.90	18.40	10.70	0	Unknown	59.1	550	NR
RDX	0.011	0.010	0.010	95	Unknown	0.018	4	NA
Perchlorate	0.07	0.038	0.072	32	Unknown	0.18	100	NA

* Value greater than the human health risk criteria.
NA – Not Analyzed ?
@STD – Standard Deviation
Ho – Null Hypothesis

7.12 SUMMARY OF PROBLEMS

Three issues were encountered during this site investigation. First, the detection of RDX and perchlorate in samples collected from the reference site has led to some uncertainty as to the use of this area as a valid background site. Second, background levels of arsenic and several manganese samples exceeded the human health risk criteria established in the JPG DQOs. Third, antimony sample values were rejected during third party data validation due to their low Laboratory Control Sample (LCS) recoveries.

Although the reference site had no visible signs of impact from military munitions, or any other activities that may have resulted in the presence of target analytes, uncertainty exists as to the

exact activities that may have taken place within this area throughout the duration of JPG's existence. Unlike within the study sites, there were no visual signs of munitions-related activities within the reference site. There was also no signal from the magnetometer handled by EOD technicians signaling the presence of UXO in the area. As a result, detections of RDX and perchlorate within this area would be questionable. The data was third party validated. There is no evidence of sampling or laboratory error. Reference surface water and sediment samples also were found to contain munitions constituents. For these reasons, we believe that the reference sample results are valid as reported. Because the low levels that were reported do not exceed the human health criteria, no additional sampling is recommended.

7.12.1 Arsenic and Manganese

Reference site/background levels of arsenic exceeded the human health risk criteria of 0.039mg/kg identified in the JPG DQOs. An alternate health risk criteria for arsenic may need to be established to take naturally occurring arsenic into account on a regional basis. Though mean concentrations of manganese were not found to be above the human health risk criteria, several individual samples were found to have concentrations higher than the criteria.

7.12.2 Rejected Antimony Values

Fifty-nine of the nondetected values for antimony in sample group WO#6360 were rejected due to their low LCS recoveries (SAIC, 2003).

7.13 DATA QUALITY INDICATORS (DQI)

The DQI refer specifically to five areas that measure to some degree both quantitative and qualitative performance criteria of the project data. The performance criteria are precision, accuracy, representativeness, comparability, and completeness, also known as PARCCs.

7.13.1 Precision

Precision measures the reproducibility of the data. QA/QC samples were used to measure this parameter. The analytical result of one sample was compared to the associated split and/or duplicate sample result using the following equation:

Equation 1

$$RPD = (S - D)/((S+D)/2) \bullet 100$$

Where:

RPD = relative percent difference
S = sample result
D = duplicate/split sample result

The RPD goal for this project was defined at 50% for both organic (explosives) and inorganic (metals) data. A total of 16 split and 16 duplicate samples were collected.

7.13.2 Accuracy

Accuracy/bias is a measure of the bias that exists in a measurement system and is also the degree of agreement between a sample's theoretical and observed concentrations. When the measurement is applied to a particular set of observed values, it will be a combination of two components: a random component and common systematic error (or bias) component. Field sampling accuracy is usually assessed with equipment rinse blanks. As only dedicated sample equipment was used, no rinse blank samples were collected. All analytical data was validated by an independent review. The review included an evaluation of QC sample data for all of the samples collected. Based on this review, all of the analytical results reported were considered valid and subsequently accurate.

7.13.3 Representativeness

Representativeness is the degree to which data accurately characterize a population, parameter variations at a sampling point, a process condition, or an environmental condition. The degree of representativeness is dependant on the thoroughness and proper design of the QAPP and Sampling Plans (SP) and adherence to its prescribed procedures, especially regarding the assumptions made during the development and the statistical soundness of the sampling design. For this investigation, the study area was divided into a number of stratum based upon available information and observations that were made. Within these given strata, each stratum was assumed to be more or less homogenous within its given areas with respect to usage, topography and vegetation. The variability of the data, the number of samples collected, screening criteria/action levels, and the DQOs all contribute to determining whether or not a sufficient number of samples were collected to fully characterize each of the strata sampled. The following equation was used to assess the representativeness of the data:

Equation 2

$$n = ([t_{1-\alpha} + t_{1-\beta}]^2 s^2/\Delta^2) + t_{1-\alpha}^2/2$$

where:

n = number of required samples
s = variance (analyte specific)
Δ = Human health screening value – observed average concentration (analyte specific)
t = Student t-value for 1-alpha (confidence – 80%); and for 1-beta (power – 95%)

Using the above equation, the number of samples collected was determined to be sufficient for characterizing the majority of the metals that were analyzed. The number of samples collected and analyzed for this study was sufficient to assess the representativeness of the data for the following reasons:

- concentrations of the each of the parameters being investigated as part of this study were below the human health risk criteria, and
- there are significant cost constraints associated with collecting and analyzing the number of samples required to meet the 95% Power.

7.13.4 Comparability

Comparability is an expression of the confidence with which one data set can be compared with another. Comparability is also dependent on similar QA objectives. There are no numerical values that can be placed on this concept. This involves a subjective review and evaluation process.

- Comparability of Field Data. The confidence with which one data set can be compared with another was dependent upon the proper design of the sampling program and testing protocols, and ensuring that the field procedures were followed as outlined in the soil sampling plan section of the JPG QAPP.
- Comparability of Analytical Laboratory Data. The confidence with which one data set can be compared with another in the laboratory is dependent upon the use of identical or nearly identical analytical methods and procedures.

7.13.5 Completeness

Completeness is a comparison of the amount of valid data received versus the amount that is specified in the DQOs. It may be calculated as follows; where, *RPC* is the relative percent completeness, *V* is the number of valid measurements completed (or samples collected), and *n* is the number of measurements specified in the DQOs that are required to achieve a specified level of confidence.

Equation 3

$$RPC = \frac{V}{n} \bullet 100$$

where:
RPC = Completeness
V = number of completed measurements
n = number of planned measurements

- Field Completeness Objectives. Field completeness was based on the number of samples collected versus the number of samples planned. Field completeness objectives were set at 90 % for all analytical chemistry samples, and 100 % for all field measurements (e.g., pH, conductivity, and temperature). Field completeness objectives were met for this study.
- Analytical Chemistry Completeness Objectives. Laboratory completeness was based on the numbers of samples that were shipped from the field for analyses compared to the number of valid results obtained. Laboratory completeness for this project was set at greater than 95 %. Analytical chemistry completeness objectives for antimony were not met due to low LCS recoveries in samples analyzed for this parameter as part of sample group WO# 6360. Fifty-nine of the samples analyzed for antimony were rejected upon third party validation (See section 7.13.3), resulting in 65.3% completeness for antimony.
- Completeness values are shown in Table 7-10.

TABLE 7-10 COMPLETENESS

	Completeness – Total Number of Samples Collected vs. Planned							
	Planned			Collected				
	Samples	Duplicates	Splits	Samples	Duplicates	Splits	Bias for Ecological	Completeness
Reference:	16	2	2	16	2	2	1	105
Stratum 1	16	2	2	16	2	2	2	110
Stratum 2	16	2	2	16	2	2	1	105
Stratum 3	16	2	2	16	2	2	0	100
Stratum 4	16	2	2	16	2	2	0	100
Stratum 5	16	2	2	19	2	2	1	105
Stratum 6	16	2	2	16	2	2	3	115
Stratum 7	16	2	2	16	2	2	2	110
Samples	128			128				
Duplicates	16			16				
Splits	16			16				
Bias				10				
Total	160			170				

7.14 SUMMARY

7.14.1 Metals

The only metal with a normal distribution that was significantly greater in the study site than the reference site was copper in Study Site 6. The Student t-Test was the statistical analysis method used to compare these two sites. However, the 95% UCL for the mean concentration of copper in Study Site 6 (9.48 mg/kg) was below the human health risk screening criteria for copper (2,900 mg/kg) identified in the JPG DQOs. The following datasets followed an unknown distribution and were found to be significantly greater in the study sites than in the reference site: antimony (Study Site 3), barium (Study Site 2), copper (Study Sites 1, 2, 4, and 5), and vanadium (Study Site 4). The nonparametric, Mann-Whitney (Wilcoxon) statistical method was used to compare barium, copper, and vanadium between the study sites and the reference site. Due to the large number of nondetects (> 50%), the nonparametric, Fisher's Exact test was used to compare the proportions of detects of barium at Study Site 2 with those at the reference site. Though each of these datasets was found to be significantly greater in the study site than in the reference site, the 99th percentile for each dataset was below the human health risk screening criteria for the parameter of interest.

7.14.2 Explosives

Of the explosives analyzed, only 2,4,6 trinitrotoluene, 2,4 dinitrotoluene, 2,6 dinitrotoluene, RDX, and perchlorate were found in samples collected at JPG. Upon qualitative analysis, it was determined that the explosives 2,4 dinitrotoluene and 2,6 dinitrotolune (each found in only one sample collected) and 2,4,6 trinitrotoluene (found in only two samples collected) would not be assessed due to the large number of nondetects (> 90%). RDX was found in the reference site and each of the study sites (except Study Site 2). The 99th percentile for RDX, found in Study Site 5 (0.098 mg/kg) was the highest concentration of RDX found in any of the samples analyzed as part of this investigation. This value was below the human health risk screening criteria (4 mg/kg) defined in the JPG DQOs. Perchlorate was found in the reference site and Study Sites 1, 2, 5, 6, and 7. The 99th percentile for perchlorate, found in Study Site 7 (0.0695 mg/kg) was the highest concentration of perchlorate found in any of the samples collected. This value was below the human health risk screening criteria (100 mg/kg) identified by USACHPPM for this study.

7.15 CONCLUSIONS

7.15.1 Metals

For the majority of the metals collected and analyzed as part of this soil investigation, proportions and concentrations of metals in the study sites were not significantly greater than in the reference site. The Null Hypotheses (Ho) defined for comparing the study sites to the reference sites were as follows:
For normal/lognormal distributions:
- Ho: mean metal concentration of study site <= mean metal concentration at the reference site (Ho: Study site mean<Reference site mean)

For unknown distributions:
- Ho: metal concentrations at the study site <= metal concentrations at the reference site (Ho: Study site median<Reference site median)

For proportions of detects:
- Ho: proportions of detects at the study site $\leq$ proportion of detects at the reference site (Ho: P study site<P reference site)

Soil investigators failed to reject the Null Hypothesis (Ho) for the majority of metals analyzed. Due to the human and ecological health risks associated with the false acceptance of Ho, the following decision errors were set: probability of making a Type I error (false rejection, rejecting the Null Hypothesis when it is true) set at 20% ($\alpha = 0.2$) giving a Confidence Level of 80%, and probability of making a Type II error (false acceptance, failing to reject the Null Hypothesis when it is false) set at 5% ($\beta = 0.05$), giving a 95% Power. Of the 13 metals analyzed, only for antimony (Study Site 3), barium (Study Site 2), copper (Study Sites 1, 2, 4, 5 and 6), and vanadium (Study Site 4) was it determined that the study site was significantly greater than the reference site. For these parameters, at these study sites, soil investigators rejected Ho. Though the parameters of interest for each of the datasets were significantly greater in the study site than

in the reference site, the 99th percentile for each of the datasets was below the human health risk screening criteria referenced in Appendix L, *Data Quality Objectives* in the JPG QAPP. Of the 13 metals analyzed, only copper residues appeared to be distributed throughout the impact area.

7.15.2 Explosives

Of the explosives analyzed, only RDX and perchlorate were distributed throughout the impact area. The 99th percentile for these parameters were below the human health risk screening criteria, as referenced in Appendix L, *Data Quality Objectives* in the JPG QAPP.

7.16 REFERENCES

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